# EXHIBIT A

**Consulting Services Agreement**

This Consulting Services Agreement ("Agreement") is effective _6 April __, _2019_____ ("Effective Date") by and between FCX Solar, LLC a New Hampshire, Limited Liability Company ("FCX"), and FTC Solar [_Inc___] a __Delaware Corporation ("Client"). In consideration of the mutual covenants contained herein, and for other valuable consideration the receipt and sufficiency of which are hereby acknowledged, FCX and Client agree as follows:

WHEREAS, Client desires to obtain certain services from FCX from time to time; and

WHEREAS, FCX desires to provide such services to Client on the terms set forth below.

FOR AND IN CONSIDERATION OF the premises and mutual agreements contained herein, FCX and Client agree as follows:

**Section 1. Definitions**.

"**Client Core IP**" means all Intellectual Property, conceived, developed, reduced to practice or otherwise owned by Client prior to the Effective Date.

"**Client Improvement**" means pertaining to the Client Core IP, excluding any FCX Improvement.

"**Confidential Information**" means information in tangible and/or electronic form that relates to a party's past, present, and/or future research, development, business activities, products, services and technical knowledge, that is disclosed by and designated as confidential by one party ("**Discloser**") to the other ("**Recipient**").

"**Deliverables**" means those tangible results of the performance of the Services that are created for Client by FCX and delivered pursuant to the Agreement.

"**FCX Core IP**" means all Intellectual Property, conceived, developed, reduced to practice or otherwise owned by FCX prior to the Effective Date, which, for clarity includes, the FCX damper Intellectual Property, the Intellectual Property licensed to Client as set forth in the Patent License Agreement and wind tunnel testing techniques related to the FCX damper Intellectual Property FCX Core IP documentation is attached at Appendix A to this agreement.

"**FCX Improvement**" means any invention (whether or not patentable), improvement, modification, derivative work, or variation of any invention, method, system, or technology pertaining to the FCX Core IP.

"**Intellectual Property**" means intellectual property, methodologies, templates, concepts, data, algorithms, formulas, know-how, structures, techniques, inventions, developments, processes, discoveries, improvements, programs, systems, tools, source code, object code, databases, applications, engine protocols, routines, models, displays and manuals, including any patents, patent rights, copyrights, trade secrets, trademarks, trade names, service marks and other intellectual property associated with any of the foregoing.

"**Joint IP**" means any Intellectual Property, other than any Client Core IP, Client Improvement, FCX Core IP or FCX Improvement, jointly (as determined by applicable United States law) conceived, developed, reduced to practice or otherwise created by the parties.

"**Patent License**" means that certain Patent License Agreement by and between FCX and Client in connection with this Agreement.

"**Services**" meanstheconsulting services FCX provides for the implementation of the patent rights granted to Client pursuant to that certain and the continued development of the Voyager single-axis tracker platform .

**Section 2. Services**. FCXwill use reasonable efforts to provide the Services and may utilize subcontractors to perform a portion of the Services.

**Section 3. Fees and Payment Terms**. All Services are provided on a time and materials basis at a rate of $190.00 per hour per individual. Clientwill: (i) pay all undisputed portions of the fees; (ii) reimburse all reasonable expenses incurred by FCX in the performance of the Services, including travel and lodging expenses, communication charges and other reasonable supplies; and (iii) pay all taxes, including any interest and penalties from any related deficiency (except taxes based on or measured by FCX's net income).FCX will obtain advance written permission from the Client for any expense exceeding $500.00.Clientwill pay the amounts in U.S. Dollars to FCX within thirty (30) days of the date of

invoices submitted by FCX. FCXmaycharge interest on any past due amounts at a rate of the lesser of one and one-half (1.5%) percent per month or the highest rate allowed by law, andClientwillindemnify FCX for all costs, including expenses and attorney's fees, incurred by FCX in the collection of overdue payments. An invoice is "disputed" if Client notifies FCX of a good faith dispute within five (5) days of receipt of invoice.

**Section 4. Mutual Confidentiality**.During the course ofFCX performing Services for Client, each party may be given access to the other party's Confidential Information. Recipient agrees to: (i) protect Discloser's Confidential Information in a reasonable and appropriate manner to the same extent it protects the confidentiality of its own proprietary and confidential information of like kind, but in no event less than a reasonable manner; and (ii) use, reproduce and disclose Discloser's Confidential Information only to perform its obligations and exercise its rightspursuant to the Agreement. Recipient may share Discloser's Confidential Information with its employees and third parties thatassist Recipient in its performance of its obligations and the exercise of its rights pursuant to the Agreement and who are subject to non-disclosure obligations no less restrictive than those set forth herein. The obligations set forth in this Section will not apply to information which is: (a) publicly known; (b) already known to the Recipient; (c) disclosed to Recipient by a third party who is not, to Recipient's knowledge, under a confidentiality restriction with respect to such Confidential Information; or (d) independently developed by the Recipient. Disclosure of Confidential Information pursuant to applicable law, a subpoena or other validly issued administrative or judicial process will not be a breach of Recipient's obligations, provided thatRecipient willprovideprior notice to Discloser of such disclosure if permitted by law. Notwithstanding anything to the contrary in this Agreement, Client agrees and hereby grants to FCX the right to use Client's name and logo in FCX's Client credentials and for marketing and publicity purposes associated with FCX's Client credentials, as well as in case studies or press releases related to FCX's performances of Services to Client.

**Section 5. Intellectual Property Ownership**.

5.1. FCX Intellectual Property. FCX owns all right, title, and interest in and to: (a) the FCX Core IP and any FCX Improvement created by FCX or Client (including any FCX Improvement that is jointly created with Client), jointly or alone and (b) except for any Joint IP (defined below) any other Intellectual Property it develops that is not a Client Improvement. Without further consideration, Client hereby irrevocably assigns to FCX all right, title and interest Client has or acquires in and to any FCX Improvement, including without limitation all Intellectual Property rights thereto. For clarity, FCX does not grant Client an rights to use the FCX Core IP or FCX Improvement under this Agreement as any rights are provided under the Patent License.

5.2 Client Intellectual Property. Client owns all right, title, and interest in and to: (a) the Client Core IP and any Client Improvement created by Client or FCX, jointly or alone (including any Client Improvement that is jointly created with FCX) and (b) except for any Joint IP (defined below) any other Intellectual Property it develops that is not a Client Improvement. Without further consideration, FCX hereby irrevocably assigns to Client all right, title and interest FCX has or acquires in and to any Client Improvement, including without limitation all Intellectual Property rights thereto.

5.3 Joint IP. FCX and Client will each own an equal undivided interest in all Joint IP. Except for Joint IP which is protected by a patent as set forth in Section 5.4, each Party may fully practice and exploit its rights in such Joint IP and grant these same rights to any third party without the obligation to account to the other Party.

5.4 Patents for Joint IP. Either party may, at its own expense, file for patent protection on Joint IP, provided the party filing the patent application has given the non-filing party written notice that it intends to file the patent application and the right to cooperate with such filing. If the non-filing party elects to equally share the costs associated with any such patent application, prosecution, and/or maintenance then the patent application shall will be jointly owned by both Parties and each Party may fully practice and exploit its rights under such patent and grant these same rights to any third party without the obligation to account to the other Party. In the event one party discontinues funding any of the patent application, prosecution, and/or maintenance costs for a particular patent or patent application, that party will promptly assign its ownership interest in any such patents to the other party.

5.5 Cooperation. Each party will, at the other party's request, reasonably assist the other party in obtaining patent protection or other interests in Intellectual Property, andwill execute assignments and other instruments and documents as the other party may consider necessary or appropriate to transfer, evidence, protect, enforce or defend its Intellectual Property.

5.6 Litigation. In the event a third party infringes the Jointly IP, either party may assert any rights associated with such Jointly IP and initiate an action for infringement thereof, provided, however, that the other party is given an opportunity in advance to, at its discretion, join in the assertion and action and to share equally in the expenses and recoveries. Each party will use commercially reasonable efforts to reasonably cooperate and assist the other party in any enforcement action brought by the other party against a third party in accordance with this provision, including, without

limitation, joining the action to the extent necessary to permit the other party to maintain the suit at the other Party's expense.

**Section 6. Client Responsibilities**. Clientwill: (i) ensure that all assumptions set forth in the Agreement are accurate; (ii) provide FCX with reliable, accurate and complete information as required; (iii) make timely decisions and obtain required management approvals; (iv) furnish FCX personnel with a suitable office environment and adequate resources and supplies, as needed; (v) obtain all consents, approvals and licenses necessary from third parties required for FCX to perform its obligations under the Agreement; and (vi) retain responsibility for its compliance with all applicable federal, state/provincial and local laws and regulations. In addition, FCXwill be entitled to rely on all Client decisions and approvals made in relation to the Agreement and/or prior to its execution by the parties. Nothing in the Agreement will require FCX to evaluate, advise on, modify, confirm, or reject such decisions and approvals. As FCX is performing the Services solely for the benefit of Client, Client will indemnify FCX, its affiliates and their principals, agents and personnel against all costs, fees, expenses, damages and liabilities (including attorneys' fees and other defense costs) associated with any third party claim relating to or arising as a result of FCX's provision of the Services, Client's use of the Deliverables, or the Agreement, excluding claims addressed in the Section herein entitled "Infringement Indemnification". As the timely performance of Client obligations and the accuracy of any assumptions set forth in an SOW are material to FCX's ability to provide the Services, in the event Client does not perform Client obligations in a timely manner, or the assumptions are not accurate, FCX has the right to suspend Services, and FCXwill not be responsible for any loss, damage or expense resulting from such suspension.

**Section 7. Limited Warranty.**

7.1 Services Warranty. FCX warrants that the Services will be performed with reasonable care in a diligent and workmanlike manner. FCX's sole obligation and liability and Client's sole and exclusive remedy for breach of this warranty will be for FCX to reperform any Services brought to its attention within thirty (30) days after the Services are performed.

7.2 Third-Party Products. FCX does not warrant and is not responsible for any third party products or services, if any. Client's sole and exclusive rights and remedies with respect to any third party products or services are against the third party vendor and not against FCX.

7.3 Disclaimer. SECTION 7.1 CONTAINS FCX'S ONLY WARRANTY ARISING OUT OF PROVISION OF THE SERVICES AND DELIVERABLES, AND IS MADE EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES, CONDITIONS AND REPRESENTATIONS, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTIES AND CONDITIONS OF MERCHANTABILITY, MERCHANTABLE QUALITY, NON-INFRINGEMENT, INFORMATIONAL CONTENT, SYSTEMS INTEGRATION, INTERFERENCE WITH ENJOYMENT, FITNESS FOR A PARTICULAR PURPOSE, OR OTHERWISE.

**Section 8. Risk Allocation.**

8.1 Cap on Liability. FCX'S TOTAL LIABILITY ARISING OUT OF THE AGREEMENT FOR ALL CLAIMS IN ANY MANNER ARISING IN CONNECTION WITH THE AGREEMENT (WHETHER IN CONTRACT, TORT, NEGLIGENCE, STRICT LIABILITY IN TORT OR BY STATUTE OR OTHERWISE, WHETHER ARISING FROM CONTRACTUAL OR EXTRA-CONTRACTUAL LIABILITY) WILL BE THE PAYMENT OF DIRECT DAMAGES AND SUCH DAMAGES IN NO EVENT WILL: (I) EXCEED IN THE AGGREGATE THE FEES FCX RECEIVES HEREUNDER IN THE TWELVE (12) PRIOR TO THE FIRST CLAIM BROUGHT BY CLIENT UNDER THIS AGREEMENT; OR (II) INCLUDE ANY INDIRECT, SPECIAL, CONSEQUENTIAL, INCIDENTAL, PUNITIVE OR EXEMPLARY DAMAGES OR LOSS (INCLUDING BUSINESS INTERRUPTION, LOST PROFITS, LOST SAVINGS OR LOST BUSINESS), EVEN IF IT HAS BEEN ADVISED OF THEIR POSSIBLE EXISTENCE.

8.2 Indemnification. Client will indemnify, defend and hold harmless FCX and its agents, employees, contractors, officers, directors and customers (each a "FCX Indemnitee") from any loss, liability, damage, cost or expense (including, without limitation, reasonable attorneys' fees) (collectively, "***Losses***"), incurred by an FCX Indemnitee in connection with any third party claim, suit, demand or investigation (collectively, "***Claims***"), to the extent arising out of: (a) any breach or alleged breach by Client of any of its obligations under this Agreement; (b) Client's non-compliance with any applicable law; (c) any injury or death of persons, damage to property, or any other damage or loss arising out of or in connection with the sale or provision of any products or services by Client or its affiliates, including any alleged defects, imperfection, and/or inherent dangers (whether obvious or hidden) in such products or services or the use thereof, or any other product liability issues or claims with respect to such products or services; (d) claims made by Client or its affiliates to the public or prospective or actual customers relating to any products or services provided by Client or its affiliates and (e) any willful misconduct or grossly negligent conduct of Client; provided however, such obligation of indemnification will not apply to the extent any Losses or Claims that result from the gross negligence or willful misconduct of an FCX Indemnitee.

**Section 9. Term; Termination**

9.1 Term. This Agreement will commence upon the Effective Date and will continue for one (1) year unless and until terminated as provided herein. ("Initial Term"). The Agreement may be renewed or extended in writing for any period as may be mutually agreed to by the parties ("Extended Term"). (the Initial Term and any Extended Term, the "Term").

9.2 Termination for Convenience. This Agreementmay be terminated at any time for convenience by either party upon thirty (30) days' notice to the other.

9.2 Termination for Cause. Either party may, upon giving thirty (30) days' notice identifying specifically the basis for such notice, terminate an Agreement for the material breach of such Agreement unless the breaching party cures such breach within the thirty (30) day period.

9.3 Consequences of Termination. In the event of termination other than Termination for Cause, Clientwill pay FCX for all Services rendered and expenses incurred as of the date of termination, andwill reimburse FCX for all unrecovered costs incurred by FCX in anticipation of providing the Services during the term of the Agreement.In the event of Termination for Cause on the part of Client, Client will pay FCX all Services rendered, and expenses incurred as of the date of termination, and will reimburse FCX for all unrecovered costs incurred by FCX in anticipation of providing the Services during the term of the Agreement. In the event of Termination for Cause on the part of FCX, Client will pay FCX only for those agreed expenses incurred as of the date of termination. Client will have no obligation for cost incurrend in anticipation of providing service to Client. The following sections survive the termination or expiration of this Agreement: 3 (with respect to any amounts owed prior to expiration or termination), 4, 5, 7.3, 8, 9.3, and 10.

**Section 10. General**

10.1 Assignment. This Agreement may not be assigned or otherwise transferred without the prior approval of the other party, which will not be unreasonably withheld or delayed. Notwithstanding the foregoing, in the event of an acquisition of all or substantially all of a party's assets or equity, such party may assign this Agreement to the acquiring company.

10.2 Notices. Any notices given pursuant to the Agreement will be in writing, delivered via registered mail, overnight mail, courier, or personal delivery, to the address set forth below, and will be considered given when received. Either party may change the name or address to which notices or other communications are to be sent by giving notice of such change to the other party. Notices shall be provided to the parties as follows:

FCX Solar LLC
c/o Frank Oudheusden
3 Lamson Road
Mont Vernon, NH 03057

FTC Solar Inc.
c/o Anthony Etnyre
11801 Domain Blvd. 3rd Floor
Austin, TX 78758

10.3 Independent Contractor. The Agreement does not make either party an agent or legal representative of the other party, and does not create a partnership or joint venture. Both parties are independent contractors and principals for their own accounts.

10.4 Insurance. Each party will determine the types and amounts of insurance coverage it requires in connection with the Agreement. Neither party is required to obtain insurance for the benefit of the other party.

10.5 No Benefits for Third Parties. Nothing contained in the Agreement, whether express or implied, is intended, or will be deemed, to create or confer any right, interest or remedy for the benefit of any person other than the parties hereto and their successors in interest and their actual permitted assignees.

10.6 Residuals. In no event willFCX be precluded from developing for itself, or for others, anything, whether in tangible or non-tangible form, which is competitive with, or similar to, the Deliverables. In addition, FCXwill be free to use the general knowledge, skills and experience of its personnel, and any ideas, concepts, know-how, and techniques that are acquired or used in the course of providing the Services.

10.7 Miscellaneous. Each Agreement constitutes the full and complete statement of the agreement of the parties with respect to the subject matter thereof and supersedes any previous agreements, understandings or communications, whether written or oral, express or implied, relating to such subject matter. If there is a conflict between the terms and conditions set forth in this Agreement and the terms and conditions of a Statement of Work, the terms and conditions set forth in this Agreementwill govern. The word "including" will be construed to mean "including, without limitation". The word "or" will mean "and/or" unless the context requires otherwise. The words "day," "month," and "year" mean, respectively, calendar day, calendar month and calendar year. The laws of the State of Delaware and the associated federal laws thereto, will govern the Agreement, without giving effect to the conflict of law rules thereof, if applicable. The parties expressly agree to exclude the application of the U.N. Convention on Contracts for the International Sale of Goods (1980) to the Agreement and the performance of the parties contemplated herein, to the extent that such convention might otherwise be applicable. No action, regardless of form, arising out of, relating to or in any way connected with the Agreement, Services or Deliverables may be brought by either party more than one (1) year after the cause of action has accrued. Neither party will be liable for any delays or failures in performance (other than payment obligations hereunder) due to circumstances beyond its reasonable control. No term of the Agreement will be deemed waived, and no breach of the Agreement excused, unless the waiver or consent is in writing signed by the party granting such waiver or consent. No amendment to the Agreement will be effective unless in writing and signed by the parties. If any term or provision of the Agreement is determined to be illegal or unenforceable, such term or provision will be deemed stricken, and all other terms and provisions will remain in full force and effect.ThisAgreement may be executed in one or more counterparts and/or by facsimile or electronic submission, each of which will be deemed an original and all of which signed counterparts, taken together, will constitute one instrument.

IN WITNESS WHEREOF, the parties have executed this Agreement as of the Effective Date through their duly authorized representatives.

ACCEPTED BY:
**FCX Solar, LLC**

4/6/2019
Authorized Signature

FRANK ANDHEUSDEN, Owner
Printed Name and Title

ACCEPTED BY:
FTC Solar, Inc.

Authorized Signature

Anthony P. Etnyre, CEO
Printed Name and Title

# FCX Solar Confidential Technology

## FCX SOLAR SINGLE-AXIS TRACKER IP / PATENT DISCLOSURE

4.5. 19

Presented To: FTC Solar

Frank Oudheusden – FCX Solar

Chris Needham – FCX Solar

FCX sol

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 31779709 |
| **Application Number:** | 62629931 |
| **International Application Number:** | |
| **Confirmation Number:** | 2831 |
| **Title of Invention:** | SOLAR TRACKER SYSTEM |
| **First Named Inventor/Applicant Name:** | Christopher Thomas Needham |
| **Customer Number:** | 22918 |
| **Filer:** | Brian R. Coleman/Crystal Fong |
| **Filer Authorized By:** | Brian R. Coleman |
| **Attorney Docket Number:** | 128682-8001.US00 |
| **Receipt Date:** | 13-FEB-2018 |
| **Filing Date:** | |
| **Time Stamp:** | 15:47:52 |
| **Application Type:** | Provisional |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $140 |
| RAM confirmation Number | 021418INTEFSW15490800 |
| Deposit Account | |
| Authorized User | |

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Application Data Sheet | ADS_1.pdf | 322777<br>de504ce6679e83dc97a06bc6ab1c0cf6960d4014 | no | 8 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| This is not an USPTO supplied ADS fillable form | | | | | |
| 2 | | Specification_1.pdf | 38752<br>7b1be47a68e666cc599f837cdf6b279e266e82bd | yes | 9 |

| | Multipart Description/PDF files in .zip description | | |
|---|---|---|---|
| | **Document Description** | **Start** | **End** |
| | Specification | 1 | 7 |
| | Claims | 8 | 8 |
| | Abstract | 9 | 9 |

| | | | | | |
|---|---|---|---|---|---|
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 3 | Drawings-only black and white line drawings | Drawings_1.pdf | 155877<br>bef3be5430fcf9ceed521c53cb811e4fdc9e585f | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 4 | Fee Worksheet (SB06) | fee-info.pdf | 29727<br>5fdc56cf2bf378ecc5b74aba0ea7a15cd650cac9 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | | **Total Files Size (in bytes):** | 547133 | |

**This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.**

**New Applications Under 35 U.S.C. 111**

**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

**National Stage of an International Application under 35 U.S.C. 371**

**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

**New International Application Filed with the USPTO as a Receiving Office**

**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | |
| **Filing Date:** | |
| **Title of Invention:** | SOLAR TRACKER SYSTEM |
| **First Named Inventor/Applicant Name:** | Christopher Thomas Needham |
| **Filer:** | Brian R. Coleman/Crystal Fong |
| **Attorney Docket Number:** | 128682-8001.US00 |

Filed as Small Entity

**Filing Fees for Provisional**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| PROVISIONAL APPLICATION FILING FEE | 2005 | 1 | 140 | 140 |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| **Petition:** | | | | |
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | | | **Total in USD ($)** | **140** |

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE



| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

## Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

## Inventor Information:

**Inventor 1** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Christopher | Thomas | Needham | |

**Residence Information (Select One)** ◉ US Residency ○ Non US Residency ○ Active US Military Service

| City | Mountain View | State/Province | HI | Country of Residence | US |
|---|---|---|---|---|---|

**Mailing Address of Inventor:**

| Address 1 | 3 Lamson Rd. | | |
|---|---|---|---|
| Address 2 | | | |
| City | Mont Vernon | State/Province | NH |
| Postal Code | 03057 | Country | US |

**Inventor 2** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Frank | Carl | Oudheusden | |

**Residence Information (Select One)** ◉ US Residency ○ Non US Residency ○ Active US Military Service

| City | Mont Vernon | State/Province | NH | Country of Residence | US |
|---|---|---|---|---|---|

**Mailing Address of Inventor:**

| Address 1 | 3 Lamson Rd. | | |
|---|---|---|---|
| Address 2 | | | |
| City | Mont Vernon | State/Province | NH |
| Postal Code | 03057 | Country | US |

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

## Correspondence Information:

**Enter either Customer Number or complete the Correspondence Information section below.**
**For further information see 37 CFR 1.33(a).**

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE



| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

| ☐ **An Address is being provided for the correspondence Information of this application.** | | | |
|---|---|---|---|
| **Customer Number** | 22918 | | |
| **Email Address** | patentprocurement@perkinscoie.com | Add Email | Remove Email |

## Application Information:

| **Title of the Invention** | SOLAR TRACKER SYSTEM | | |
|---|---|---|---|
| **Attorney Docket Number** | 128682-8001.US00 | **Small Entity Status Claimed** | ☒ |
| **Application Type** | Provisional | | |
| **Subject Matter** | Utility | | |
| **Total Number of Drawing Sheets (if any)** | 2 | **Suggested Figure for Publication (if any)** | |

## Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country |
|---|---|---|
| | | |

## Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

## Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

| Please Select One: | ◉ Customer Number | ○ US Patent Practitioner | ○ Limited Recognition (37 CFR 11.9) |
|---|---|---|---|
| Customer Number | 22918 | | |

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

## Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

| Prior Application Status | | | Remove |
|---|---|---|---|
| Application Number | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
| | | | |

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

## Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

| | | | Remove |
|---|---|---|---|
| Application Number | Country[i] | Filing Date (YYYY-MM-DD) | Access Code[i] (if applicable) |
| | | | |

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

## Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

PTO/AIA/14 (11-15)
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| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE**: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

**1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)**

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

**2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)**

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

## Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

**Applicant 1**

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

| ○ Assignee | ○ Legal Representative under 35 U.S.C. 117 | ○ Joint Inventor |
|---|---|---|
| ◉ Person to whom the inventor is obligated to assign. | ○ Person who shows sufficient proprietary interest | |

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

| Organization Name | FCX Solar LLC | | |
|---|---|---|---|
| **Mailing Address Information For Applicant:** | | | |
| **Address 1** | 3 Lamson Rd. | | |
| Address 2 | | | |
| **City** | Mont Vernon | **State/Province** | NH |
| **Country** | US | Postal Code | 03057 |
| Phone Number | | Fax Number | |
| Email Address | | | |

Additional Applicant Data may be generated within this form by selecting the Add button.

## Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

**Assignee 1**

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

| Prefix | **Given Name** | Middle Name | **Family Name** | Suffix |
|---|---|---|---|---|
| | | | | |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

| | | | |
|---|---|---|---|
| **Address 1** | | | |
| Address 2 | | | |
| **City** | | **State/Province** | |
| **Country** | | Postal Code | |
| Phone Number | | Fax Number | |
| Email Address | | | |

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

## Signature:

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

| **Signature** | /brian r. coleman/ | | | Date (YYYY-MM-DD) | 2018-02-13 |
|---|---|---|---|---|---|
| First Name | Brian R. | Last Name | Coleman | Registration Number | 39,145 |

Additional Signature may be generated within this form by selecting the Add button.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US00 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

# SOLAR TRACKER SYSTEM

**[0001]** The present application is related to solar tracker systems for solar panels.

## BACKGROUND

**[0002]** Photovoltaic (PV) power systems frequently track the sun to various degrees to increase an amount of energy produced by the system. These trackers typically move photovoltaic modules to adjust an angle of incidence of the sunlight on the surface of the PV modules. In particular, trackers typically rotate the PV modules around an axis principally oriented north to south, tilting the modules to as much as 60 degrees towards the east and west and adjusting tilt within this range throughout the day. By tracking the position of the sun, PV power systems often produce 20-30% more energy than fixed-tilt systems.

**[0003]** A common configuration of horizontal single-axis trackers ("SAT") as described above includes a single actuator near the center of a row of PV modules, potentially with 80-120 modules tilted by a single actuator. The angle of tilt is defined by the position of the actuator, while a torque tube or other similar device transfers moments and positions the rest of the row at this tilt. However, environmental loading (wind, snow, dead load, etc.) can twist portions of a row away from the intended tilt angle. This effect requires design considerations that add cost in order to decrease risk of failures.

**[0004]** To reduce row twist, some PV systems may have shorter row lengths or more than one actuator per row. These approaches can reduce the risk of system failure from excessive row twist, but may increase the PV system cost as well as overhead and maintenance costs. Furthermore, when multiple actuators are used, the actuators within a row must communicate such that, for example, other actuators stop moving if one actuator fails. This communication can be by electronic, mechanical, or other means. However, this active control brings additional failure modes that must be considered in the design of the PV system.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0005]** FIG. 1 illustrates a photovoltaic system, according to one embodiment.

**[0006]** FIG. 2 illustrates an example Durst curve.

**[0007]** The figures depict various embodiments of this disclosure for purposes of illustration only. One skilled in the art can readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein can be employed without departing from the principles of the invention described herein.

DETAILED DESCRIPTION

**[0008]** FIG. 1 illustrates a photovoltaic (PV) system 100, according to one embodiment. As shown in FIG. 1, the PV system 100 may include a collection of PV modules110, an actuator 120, a controller 130, and a damper 140. The PV system 100 is configured to generate electricity, and may be used alone or with other similar photovoltaic systems in, for example, a photovoltaic power station.

**[0009]** The collection of PV modules 110 includes an array of one or more photovoltaic modules configured to convert solar energy into electricity by the photovoltaic effect. The collection of PV modules 110 is rotatably anchored to a base 115, and may be coupled to a power grid, battery, or other power transmission or storage system. The amount of electricity produced by each photovoltaic module may be a function of the angle of incidence of light on the surface of the module, where more energy is captured when light is perpendicular to the surface (*i.e.,* a zero-degree angle of incidence) than when light is incident at higher angles.

**[0010]** The actuator 120is configured to rotate the collection of PV modules 110 around one or more axes. The actuator 120 may be a linear actuator coupled to the PV module collection 110 and a fixed position, such as the base 115. Increasing or decreasing the length of the linear actuator changes a tilt angle of the collection of PV modules 110 with respect to the base 115. Other types of actuators may be used in other embodiments. For example, the PV module collection 110 may be mounted on an axle and a rotary actuator may drive the axle to rotate the collection of PV modules 110 around an axis. In one embodiment, the actuator 120 rotates the collection of PV modules 110 around an axis centered at the base 115 and geographically oriented substantially north to south, such that a surface of the PV module 110 can be tilted between east- and west-facing angles. The actuator 120 may also rotate the collection of PV modules 110 around additional axes (*e.g.,* an east-west axis), or the photovoltaic system 100 may include one or more additional actuators to cause other movements of the collection of PV modules 110.

**[0011]** The controller 130 drives the actuator 120 to set a tilt angle of the collection of PV modules 110. To increase the amount of energy captured by the collection of PV

modules 110, the controller 130 may set the tilt angle based on a position of the sun. In one embodiment, the controller 130 is coupled to a light sensor (not shown in FIG. 1) to detect a position of the sun during the day. As the day progresses, the controller 130 may drive the actuator 120 to move the PV module collection 110 to follow the detected movement of the sun. Thus, the controller 130 drives the actuator 120 to move the PV module collection 110 from an orientation facing substantially east to an orientation facing substantially west. Overnight, the controller 130 may drive the actuator 120 to return the collection of PV modules 110 to an east-facing orientation in preparation for sunrise the next morning, or the controller 130 may drive the actuator 120 to rotate the PV module collection 110 in response to detecting sunlight in the east. The controller 130 may alternatively control the tilt angle of the PV module collection 110 without light feedback, for example based on time of day.

**[0012]** The damper 140 provides damping for the PV system 100 to mitigate dynamic wind loading or other vibrational loads applied to the PV system 100. Wind loading can induce motion in PV system 100, for example rotating the collection of PV modules 110 around the base at a velocity multiple orders of magnitude higher than the motion induced by the actuator 120. Although the damper 140 is shown in FIG. 1 as a component separate from the actuator 120 for purposes of illustration, the damper 140 may be incorporated into or positioned concentric to the actuator 120.

**[0013]** The damper 140 has a damping ratio that varies as a function of the operating state of the actuator 120. Different damping ratios may be advantageous for different operating states. For example, a high damping ratio enables the damper 140 to dissipate more energy, and therefore better mitigates undesired oscillations of the PV system 100 under wind loading than a low damping ratio. A high damping ratio also potentially enables the damper 140 to bear a portion of the static load of the PV module collection 110 and dynamic loads caused by environmental conditions, reducing the load on the actuator 120. However, a high damping ratio may cause the damper 140 to resist movement of the actuator 120. The resistance may twist the PV module 110 away from its intended orientation with respect to the sun. As a result of the modified angle of incidence

caused by this "propeller effect," the collection of PV modules 110 may generate less electricity. If twisted more than a few degrees, operation of the collection of PV modules 110 may fall outside acceptable specifications. A low damping ratio, in contrast, reduces the twist by providing lower resistance to movement of the actuator 120.

**[0014]** Accordingly, the variable damping ratio of the damper 140 may be relatively low at low speeds (*e.g.,* while the actuator 120 is moving the collection of PV modules 110) and relatively high at higher speeds (*e.g.,* under dynamic wind loading). The higher damping ratio of the damper 140 may enable the damper 140 to support a portion of the loading on the PV system 100, including the static load of the PV module collection 110 (*e.g.,* the weight of the collection 110) and static or dynamic loading caused by environmental conditions such as wind, snow, or dust. The lower damping ratio reduces the damper's resistance to movement caused by the actuator 120. The damping ratio of the damper 140 may be adjusted passively based on the operating state of the actuator 120, such as the actuation rate. The damping ratio may therefore be adjusted without active control by the controller 130.

**[0015]** In one embodiment, the damper 140 includes a damper piston with a small diameter port and a large diameter port, where the large diameter port is controlled by a valve. The damper piston moves through fluid contained in a damper chamber. At low speeds, the fluid can flow freely through the large diameter port and provide little resistance to the movement of the piston. At higher speeds, the valve is pushed closed and the fluid is forced through the small diameter port. The resistance provided by the fluid flow through the small diameter port increases the effective damping ratio of the damper 140.

**[0016]** Other embodiments of the damper 140 may passively regulate the damping ratio in other manners. For example, valves may regulate fluid flow through multiple equally or differently sized ports in the damper piston. At lower speeds, the valves are open to allow the fluid to flow through several or all of the ports. At higher speeds, the valves close the port and force the fluid to flow through a smaller number of ports. As another example, the damper 140 may include a non-Newtonian fluid that has lower viscosity at low piston speeds and higher viscosity at high piston speeds.

**[0017]** The PV system 100 may be designed based on wind speed in the area where the system will be installed. In particular, the PV system 100 may be designed to withstand expected peak loads from the area's wind conditions following a protocol such as ASCE 7. FIG. 2 illustrates an example Durst curve, which relates average wind speed to gust duration, that may be used in such protocols. As shown in FIG. 2, average wind speeds are higher for shorter measurements of gust duration than for longer measurements. Because the damper 140 has a higher damping ratio under wind loading and bears a portion of the load on the collection of PV modules 110, the PV system 100 may be designed based on longer gust durations--and therefore lower wind speeds--than photovoltaic systems lacking the damper 140. The design for lower wind speeds may reduce the amount of material used to construct the base 115, the actuator 120, and the collection of PV modules 110, and may reduce overhead and maintenance costs for the PV system 100.

Remarks

**[0018]** The foregoing description of various embodiments of the claimed subject matter has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the claimed subject matter to the precise forms disclosed. Many modifications and variations can be apparent to one skilled in the art. Embodiments were chosen and described in order to best describe the principles of the invention and its practical applications, thereby enabling others skilled in the relevant art to understand the claimed subject matter, the various embodiments, and the various modifications that are suited to the particular uses contemplated.

**[0019]** While embodiments have been described in the context of fully functioning computers and computer systems, those skilled in the art can appreciate that the various embodiments are capable of being distributed as a program product in a variety of forms, and that the disclosure applies equally regardless of the particular type of machine or computer-readable media used to actually effect the distribution.

**[0020]** Although the above Detailed Description describes certain embodiments and the best mode contemplated, no matter how detailed the above appears in text, the

embodiments can be practiced in many ways. Details of the systems and methods can vary considerably in their implementation details, while still being encompassed by the specification. As noted above, particular terminology used when describing certain features or aspects of various embodiments should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless those terms are explicitly defined herein. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the embodiments under the claims.

**[0021]** The language used in the specification has been principally selected for readability and instructional purposes, and it cannot have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the invention be limited not by this Detailed Description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of various embodiments is intended to be illustrative, but not limiting, of the scope of the embodiments, which is set forth in the following claims.

# CLAIMS

What is claimed is:

1. A photovoltaic system, comprising:

a collection of photovoltaic modules;

an actuator coupled to the photovoltaic modules and configured to rotate the photovoltaic modules around an axis; and

a damper coupled to the photovoltaic modules, wherein the damper has a variable damping ratio.

2. The photovoltaic system of claim 1, further comprising:

a controller in electronic communication with the actuator and configured to drive the actuator to rotate the photovoltaic module around an axis;

wherein the damping ratio of the damper is set independently of the controller.

3. The photovoltaic system of claim 1, wherein the damper has a first damping ratio while the actuator is rotating the photovoltaic module and a second damping ratio under wind loading of the photovoltaic module, wherein the second damping ratio is higher than the first damping ratio.

4. The photovoltaic system of claim 1, wherein the damper supports at least a portion of a load placed on the photovoltaic system by an environmental condition..

## ABSTRACT OF THE DISCLOSURE

A photovoltaic system includes photovoltaic modules and an actuator and a damper coupled to the photovoltaic modules. The actuator is configured to rotate the photovoltaic modules around an axis, for example to track a position of the sun. The damper has a variable damping ratio.

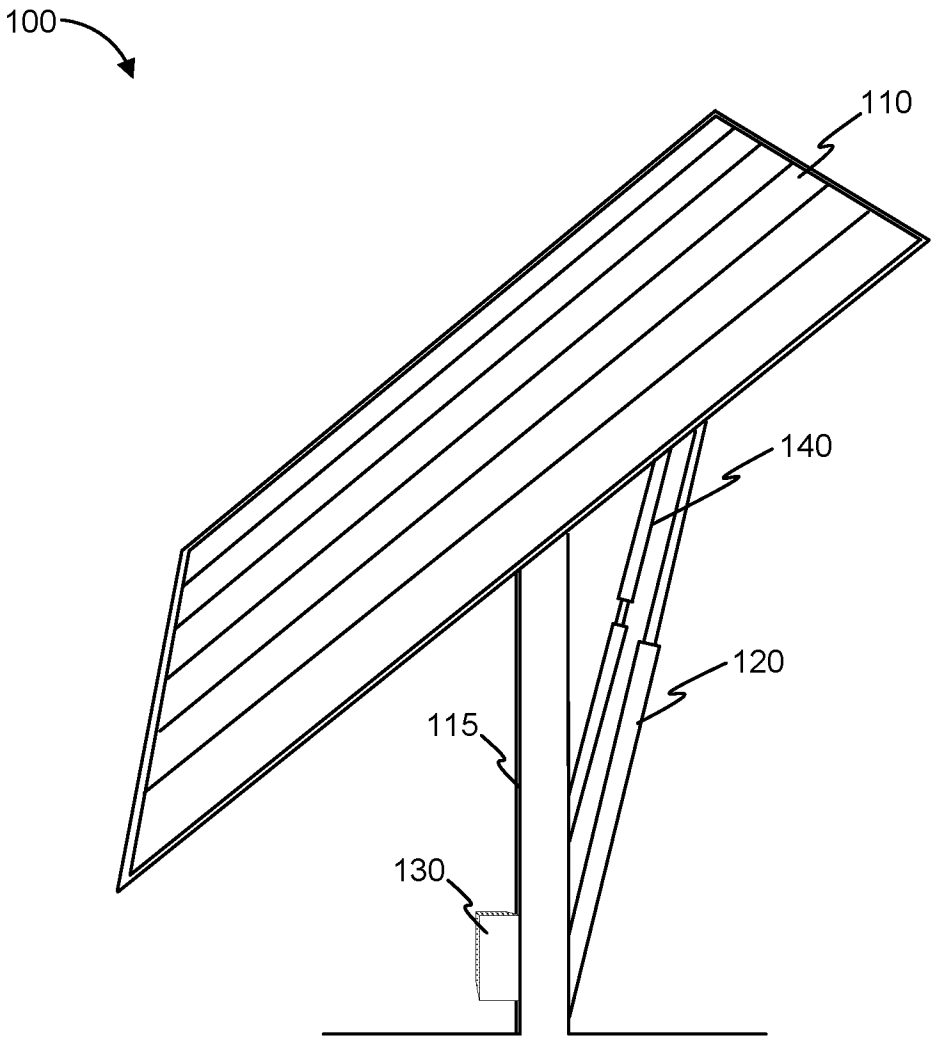


FIG. 1

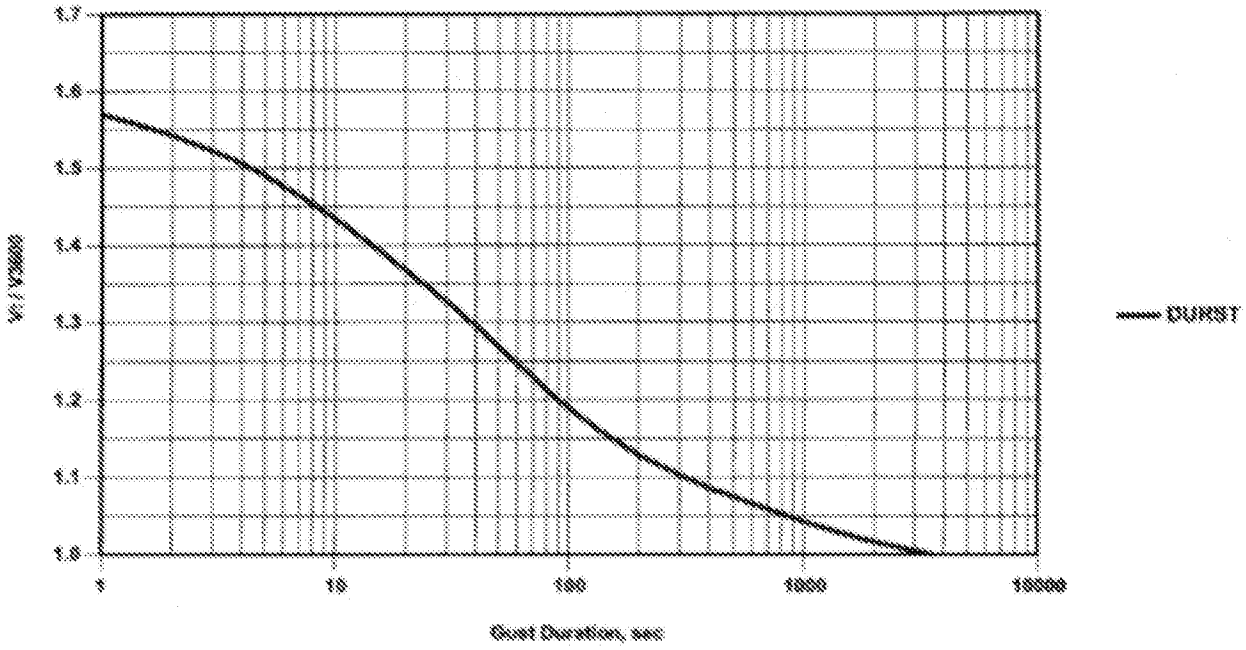


FIG. 2

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 35137902 |
| **Application Number:** | 16274557 |
| **International Application Number:** | |
| **Confirmation Number:** | 1416 |
| **Title of Invention:** | SOLAR TRACKER SYSTEM |
| **First Named Inventor/Applicant Name:** | Christopher Thomas Needham |
| **Customer Number:** | 22918 |
| **Filer:** | Kristen Leigh Schunter/Crystal Fong |
| **Filer Authorized By:** | Kristen Leigh Schunter |
| **Attorney Docket Number:** | 128682-8001.US01 |
| **Receipt Date:** | 13-FEB-2019 |
| **Filing Date:** | |
| **Time Stamp:** | 13:34:28 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $865 |
| RAM confirmation Number | 021319INTEFSW13350000 |
| Deposit Account | |
| Authorized User | |

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Power of Attorney | POA_1.pdf | 294519<br>37b9732f360e7282b222bd75de3335c446abbe1c | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Application Data Sheet | ADS_1.pdf | 323882<br>ab29bbdee3eb08fd109251c86dd6fce7f8b0e795 | no | 8 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| This is not an USPTO supplied ADS fillable form | | | | | |
| 3 | | Specification_1.pdf | 72380<br>2060e79536e6ec5951144808779da90c7c0f35ee | yes | 15 |

**Multipart Description/PDF files in .zip description**

| Document Description | Start | End |
|---|---|---|
| Abstract | 15 | 15 |
| Claims | 11 | 14 |
| Specification | 1 | 10 |

| | | | | | |
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| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 4 | Drawings-only black and white line drawings | Drawings.pdf | 349949<br>98ba841febe8b9cad33a50db37eaa08595590b16 | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |

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|---|---|---|---|---|---|
| 5 | Fee Worksheet (SB06) | fee-info.pdf | 36789<br>10510935f453672985205 6c578cba1c2c3bbf05d | no | 2 |

| | |
|---|---|
| **Warnings:** | |
| **Information:** | |
| **Total Files Size (in bytes):** | 1077519 |

**This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.**

**New Applications Under 35 U.S.C. 111**

**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

**National Stage of an International Application under 35 U.S.C. 371**

**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

**New International Application Filed with the USPTO as a Receiving Office**

**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | |
| **Filing Date:** | |
| **Title of Invention:** | SOLAR TRACKER SYSTEM |
| **First Named Inventor/Applicant Name:** | Christopher Thomas Needham |
| **Filer:** | Kristen Leigh Schunter/Crystal Fong |
| **Attorney Docket Number:** | 128682-8001.US01 |

Filed as Small Entity

**Filing Fees for Utility under 35 USC 111(a)**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| UTILITY FILING FEE (ELECTRONIC FILING) | 4011 | 1 | 75 | 75 |
| UTILITY SEARCH FEE | 2111 | 1 | 330 | 330 |
| UTILITY EXAMINATION FEE | 2311 | 1 | 380 | 380 |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| LATE FILING FEE FOR OATH OR DECLARATION | 2051 | 1 | 80 | 80 |
| **Petition:** | | | | |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| Patent-Appeals-and-Interference: | | | | |
| Post-Allowance-and-Post-Issuance: | | | | |
| Extension-of-Time: | | | | |
| Miscellaneous: | | | | |
| | | | Total in USD ($) | 865 |

PTO/AIA/82A (07-13)
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# TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

| | |
|---|---|
| Application Number | Not Yet Assigned |
| Filing Date | Concurrently Herewith |
| First Named Inventor | Christopher Thomas Needham |
| Title | SOLAR TRACKER SYSTEM |
| Art Unit | Not Yet Assigned |
| Examiner Name | Not Yet Assigned |
| Attorney Docket Number | 128682-8001.US01 |

**SIGNATURE of Applicant or Patent Practitioner**

| | | | |
|---|---|---|---|
| Signature | /Kristen Schunter/ | Date (Optional) | February 13, 2019 |
| Name | Kristen L. Schunter | Registration Number | 76,519 |
| Title (if Applicant is a juristic entity) | | | |
| Applicant Name (if Applicant is a juristic entity) | | | |

**NOTE:** This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

Doc Code: PA..
Document Description: Power of Attorney

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# POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

| Application Number | Filing Date |
|---|---|
| | |

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 22918

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

**Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:**

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

| | | | | | |
|---|---|---|---|---|---|
| Firm or Individual Name | | | | | |
| Address | | | | | |
| City | | State | | Zip | |
| Country | | | | | |
| Telephone | | Email | | | |

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

FCX Solar LLC

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

**SIGNATURE of Applicant for Patent**

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

| | | | |
|---|---|---|---|
| Signature | [signature] | Date (Optional) | 2-14-18 |
| Name | Chris Needham | | |
| Title | Co-owner | | |

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

## Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

## Inventor Information:

**Inventor 1** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Christopher | Thomas | Needham | |

**Residence Information (Select One)** ◉ US Residency ○ Non US Residency ○ Active US Military Service

| City | Mountain View | State/Province | HI | Country of Residence | US |
|---|---|---|---|---|---|

**Mailing Address of Inventor:**

| Address 1 | 3 Lamson Rd. | | |
|---|---|---|---|
| Address 2 | | | |
| City | Mont Vernon | State/Province | NH |
| Postal Code | 03057 | Country | US |

**Inventor 2** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Frank | Carl | Oudheusden | |

**Residence Information (Select One)** ◉ US Residency ○ Non US Residency ○ Active US Military Service

| City | Mont Vernon | State/Province | NH | Country of Residence | US |
|---|---|---|---|---|---|

**Mailing Address of Inventor:**

| Address 1 | 3 Lamson Rd. | | |
|---|---|---|---|
| Address 2 | | | |
| City | Mont Vernon | State/Province | NH |
| Postal Code | 03057 | Country | US |

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

## Correspondence Information:

**Enter either Customer Number or complete the Correspondence Information section below.**
**For further information see 37 CFR 1.33(a).**

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

☐ **An Address is being provided for the correspondence Information of this application.**

| | | | |
|---|---|---|---|
| **Customer Number** | 22918 | | |
| **Email Address** | patentprocurement@perkinscoie.com | Add Email | Remove Email |

## Application Information:

| | | | |
|---|---|---|---|
| **Title of the Invention** | SOLAR TRACKER SYSTEM | | |
| **Attorney Docket Number** | 128682-8001.US01 | **Small Entity Status Claimed** | ☒ |
| **Application Type** | Nonprovisional | | |
| **Subject Matter** | Utility | | |
| **Total Number of Drawing Sheets (if any)** | 3 | **Suggested Figure for Publication (if any)** | |

## Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country |
|---|---|---|
| | | |

## Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

## Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

| | | | |
|---|---|---|---|
| Please Select One: | ◉ Customer Number | ○ US Patent Practitioner | ○ Limited Recognition (37 CFR 11.9) |
| Customer Number | 22918 | | |

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

## Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

| Prior Application Status | Pending | | Remove |
|---|---|---|---|
| Application Number | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
| | Claims benefit of provisional | 62629931 | 2018-02-13 |

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

## Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

| | | | Remove |
|---|---|---|---|
| Application Number | Country[i] | Filing Date (YYYY-MM-DD) | Access Code[i] (if applicable) |
| | | | |

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

## Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE**: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

**1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)**

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

**2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)**

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

## Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

**Applicant 1**

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

| ○ Assignee | ○ Legal Representative under 35 U.S.C. 117 | ○ Joint Inventor |
|---|---|---|
| ◉ Person to whom the inventor is obligated to assign. | ○ Person who shows sufficient proprietary interest | |

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

| Organization Name | FCX Solar LLC | | |
|---|---|---|---|
| **Mailing Address Information For Applicant:** | | | |
| **Address 1** | 3 Lamson Rd. | | |
| Address 2 | | | |
| **City** | Mont Vernon | **State/Province** | NH |
| **Country** | US | Postal Code | 03057 |
| Phone Number | | Fax Number | |
| Email Address | | | |

Additional Applicant Data may be generated within this form by selecting the Add button.

## Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

**Assignee 1**

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

| Prefix | **Given Name** | Middle Name | **Family Name** | Suffix |
|---|---|---|---|---|
| | | | | |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

| | | | |
|---|---|---|---|
| **Address 1** | | | |
| Address 2 | | | |
| **City** | | **State/Province** | |
| **Country** | | Postal Code | |
| Phone Number | | Fax Number | |
| Email Address | | | |

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

## Signature:

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

| **Signature** | /Kristen Schunter/ | | | Date (YYYY-MM-DD) | 2019-02-13 |
|---|---|---|---|---|---|
| First Name | Kristen L. | Last Name | Schunter | Registration Number | 76,519 |

Additional Signature may be generated within this form by selecting the Add button.

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 128682-8001.US01 |
|---|---|---|
| | Application Number | |
| Title of Invention | SOLAR TRACKER SYSTEM | |

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

# Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

# SOLAR TRACKER SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATION

**[0001]** This application claims the benefit of U.S. Provisional Patent Application Serial No. 62/629,931, filed February 13, 2018, which is incorporated herein by reference in its entirety.

## TECHNICAL FIELD

**[0002]** The present application is related to solar tracker systems for solar panels.

## BACKGROUND

**[0003]** Photovoltaic (PV) power systems frequently track the sun to various degrees to increase an amount of energy produced by the system. These trackers typically move photovoltaic modules to adjust an angle of incidence of the sunlight on the surface of the PV modules. In particular, trackers typically rotate the PV modules around an axis principally oriented north to south, tilting the modules to as much as 60 degrees towards the east and west and adjusting tilt within this range throughout the day. By tracking the position of the sun, PV power systems often produce 20-30% more energy than fixed-tilt systems.

**[0004]** A common configuration of horizontal single-axis trackers ("SAT") as described above includes a single actuator near the center of a row of PV modules, potentially with 80-120 modules tilted by a single actuator. The angle of tilt is defined by the position of the actuator, while a torque tube or other similar device transfers moments and positions the rest of the row at this tilt. However, environmental loading (wind, snow, dead load, etc.) can twist portions of a row away from the intended tilt angle. This effect requires design considerations that add cost in order to decrease risk of failures.

**[0005]** To reduce row twist, some PV systems may have shorter row lengths or more than one actuator per row. These approaches can reduce the risk of system failure from excessive row twist, but may increase the PV system cost as well as overhead and

maintenance costs. Furthermore, when multiple actuators are used, the actuators within a row must communicate such that, for example, other actuators stop moving if one actuator fails. This communication can be by electronic, mechanical, or other means. However, this active control brings additional failure modes that must be considered in the design of the PV system.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** FIG. 1 illustrates a photovoltaic system, according to one embodiment.

**[0007]** FIGS. 2A-2C illustrate an example damper.

**[0008]** FIG. 3 illustrates an example Durst curve.

**[0009]** The figures depict various embodiments of this disclosure for purposes of illustration only. One skilled in the art can readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein can be employed without departing from the principles of the invention described herein.

DETAILED DESCRIPTION

**[0010]** FIG. 1 illustrates a photovoltaic (PV) system 100, according to one embodiment. As shown in FIG. 1, the PV system 100 may include a collection of PV modules 110, an actuator 120, a controller 130, and a damper 140. The PV system 100 is configured to generate electricity, and may be used alone or with other similar photovoltaic systems in, for example, a photovoltaic power station.

**[0011]** The collection of PV modules110includes an array of one or more photovoltaic modules configured to convert solar energy into electricity by the photovoltaic effect. The collection of PV modules 110 is rotatably anchored to a base 115, and may be coupled to a power grid, battery, or other power transmission or storage system. The amount of electricity produced by each photovoltaic module can be a function of at least the angle of incidence of light on the surface of the module, where more energy is captured when light is perpendicular to the surface (*i.e.,* a zero-degree angle of incidence) than when light is incident at higher angles.

**[0012]** The actuator 120is configured to rotate the collection of PV modules110around one or more axes. The actuator 120 may be a linear actuator coupled to the PV module collection 110 and a fixed position, such as the base 115. Increasing or decreasing the length of the linear actuator changes a tilt angle of the collection of PV modules 110 with respect to the base 115. Other types of actuators may be used in other embodiments. For example, the PV module collection 110 may be mounted on an axle and a rotary actuator may drive the axle to rotate the collection of PV modules 110 around an axis. In one embodiment, the actuator 120 rotates the collection of PV modules 110 around an axis centered at the base 115 and geographically oriented substantially north to south, such that a surface of the PV module 110 can be tilted between east- and west-facing angles. The actuator 120 may also rotate the collection of PV modules 110 around additional axes (*e.g.,* an east-west axis), or the photovoltaic system 100 may include one or more additional actuators to cause other movements of the collection of PV modules 110.

**[0013]** The controller 130drives the actuator 120 to set a tilt angle of the collection of PV modules 110. To increase the amount of energy captured by the collection of PV

modules 110, the controller 130 may set the tilt angle based on a position of the sun. In one embodiment, the controller 130 is coupled to a light sensor (not shown in FIG. 1) to detect a position of the sun during the day. As the day progresses, the controller 130 may drive the actuator 120 to move the PV module collection 110 to follow the detected movement of the sun. Thus, the controller 130 drives the actuator 120 to move the PV module collection 110 from an orientation facing substantially east to an orientation facing substantially west. Overnight, the controller 130 may drive the actuator 120 to return the collection of PV modules 110 to an east-facing orientation in preparation for sunrise the next morning, or the controller 130 may drive the actuator 120 to rotate the PV module collection 110 in response to detecting sunlight in the east. The controller 130 may alternatively control the tilt angle of the PV module collection 110 without light feedback, for example based on time of day.

**[0014]** The damper 140provides damping for the PV system 100, resisting movement of the PV modules 110 relative to the base 115. Damping by the damper 140 can mitigate dynamic wind loading or other vibrational loads applied to the PV system 100.Wind loading can induce motion in PV system 100, for example rotating the collection of PV modules 110 around the base at a velocity multiple orders of magnitude higher than the motion induced by the actuator 120. Although the damper 140 is shown in FIG. 1 as a component separate from the actuator 120 for purposes of illustration, the damper 140 may be incorporated into or positioned concentric to the actuator 120.

**[0015]** The damper 140 has a variable damping ratio. The damper 140 can have at least a first damping ratio under a first operating condition and a second damping ratio under a second operating condition. Different damping ratios may be advantageous for different operating states. For example, a high damping ratio enables the damper 140 to dissipate more energy, and therefore better mitigates undesired oscillations of the PV system 100 under wind loading than a low damping ratio. A high damping ratio also potentially enables the damper 140 to bear a portion of the static load of the PV module collection 110 and dynamic loads caused by environmental conditions, reducing the load on the actuator 120. However, a high damping ratio may cause the damper 140 to provide

enough resistance to the movement of the actuator 120 cause the PV module 110 to twist away from its intended orientation. As a result of the modified angle of incidence caused by this "propeller effect," the collection of PV modules 110maygenerate less electricity. If twisted more than a few degrees, operation of the collection of PV modules 110 may fall outside acceptable specifications. A low damping ratio, in contrast, reduces the twist by providing lower resistance to movement of the actuator 120.

**[0016]** Accordingly, the damper 140 can have a first damping ratio while the PV modules 110 move at a first rate. The damper 140 can have a second damping ratio, higher than the first damping ratio, during a second movement rate of the PV modules 110 that is higher than the first rate. For example, the damping ratio can be relatively low when the PV modules 110 move at low speeds relative to the base 115 (*e.g.,* while the actuator 120 is moving the collection of PV modules 110 without high environmental loading) and relatively high when the PV modules 110 move at higher speeds relative to the base (*e.g.,* under dynamic wind loading). The higher damping ratio of the damper 140 may enable the damper 140 to support a portion of the loading on the PV system 100, including the static load of the PV module collection 110 (*e.g.,* the weight of the collection 110) and static or dynamic loading caused by environmental conditions such as wind, snow, or dust. The lower damping ratio reduces the damper's resistance to movement caused by the actuator 120. The damping ratio of the damper 140 can change passively based on the operating state of the actuator 120, such as the actuation rate. The damping ratio may therefore be adjusted without active control by, for example, the controller 130.

**[0017]** The higher damping ratio can have a value greater than 1 (such that the PV system 100 is overdamped), while not fully locking up the PV system 100 under loading by wind or other environmental conditions. That is, the damper 140 under the higher damping ratio allows some movement of the system 100 while providing resistance against that movement. However, in some embodiments, the damper 140 may fully lock up under high environmental loading.

**[0018]** FIGS. 2A-2C show one example damper 140. FIG. 2A is a bottom cutaway view of the damper 140, while FIGS. 2B-2C are a side cutaway view of the damper. The

damper 140 can include a damper piston 210 that can move through fluid contained in a damper chamber 205. Any fluid or mixture of fluids can be contained within the damper chamber 205, such as air, water, or oil. The damper piston 210 includes at least two ports 215 that, when open, allow fluid to flow between the damper piston and damper chamber. The ports 215 are shown in FIG. 2A as being openings in a bottom end of the damper piston, but the ports can be located anywhere in the damper piston.

**[0019]** The two ports 215 can include at least one smaller diameter port 215Aand at least one larger diameter port 215B. The larger diameter port 215A can be controlled by a valve 220. When the damper piston 210 moves through the fluid at low speeds (*e.g.,* while the PV modules 110 are rotated at a low speed by the actuator 120), the fluid can flow freely through the large diameter port 215B and provide little resistance to the movement of the piston. FIG. 2B illustrates an example of the piston 210 moving at a low speed through the fluid. As shown in FIG. 2B, the valve 220 is open and fluid can pass through the larger diameter port 215B to flow into or out of the damper piston 210. At higher speeds, the valve 220 is pushed closed and the fluid is forced through the smaller diameter port 215A. The resistance provided by the fluid flow through the small diameter port 215A increases the effective damping ratio of the damper 140. FIG. 2C illustrates an example of the piston 210 moving at a high speed through the fluid. As shown in FIG. 2C, the valve 220 is closed and fluid is forced through the smaller diameter port 215A to flow into or out of the damper piston 210.

**[0020]** The damper 140 may have configurations other than that shown in FIGS. 2A-2C and may passively regulate the damping ratio in other manners. For example, valves may regulate fluid flow through multiple equally or differently sized ports in the damper piston. At lower speeds, the valves are open to allow the fluid to flow through several or all of the ports. At higher speeds, the valves close the port and force the fluid to flow through a smaller number of ports. As another example, the damper 140 may include a non-Newtonian fluid that has lower viscosity at low piston speeds and higher viscosity at high piston speeds.

**[0021]** The PV system 100 may be designed based on wind speed in the area where

the system will be installed. In particular, the PV system 100 may be designed to withstand expected peak loads from the area's wind conditions following a protocol such as ASCE 7. FIG. 3 illustrates an example Durst curve, which relates average wind speed to gust duration, that may be used in such protocols. As shown in FIG. 3, average wind speeds are higher for shorter measurements of gust duration than for longer measurements. Because the damper 140 has a higher damping ratio under wind loading and bears a portion of the load on the collection of PV modules 110, the PV system 100 may be designed based on longer gust durations--and therefore lower wind speeds--than photovoltaic systems lacking the damper 140. Furthermore, while the Durst curve shown in FIG. 3 assumes free, unobstructed wind speed, the PV system 100 will likely experience turbulent air flow as dynamic winds move around the structure. The average moments on the PV system 100 under turbulent flow may be even lower across longer gust durations than predicted by the Durst curve. Accordingly, at least one of the base 115, the actuator 120, and the PV modules 110 can be designed to withstand an average value of moments applied to the PV system 100 across a specified duration of time. This duration of time can be calculated based on wind tunnel testing, and can be, for example, approximately equivalent to a response time of the PV system 100 under target environmental loads. The design for lower wind speeds may reduce the amount of material used to construct the base 115, the actuator 120, and the collection of PV modules 110, and may reduce overhead and maintenance costs for the PV system 100.

**[0022]** In some embodiments, the higher damping ratio of the damper 140 is designed under wind tunnel testing to achieve a specified response time of the PV system 100 under high environmental loads. Because the higher damping ratio resists movement of the actuator 120, it may take longer for the actuator 120 to move the PV modules 110 to a specified angle under the higher damping ratio than under the lower damping ratio. The higher damping ratio can be selected such that the movement of the PV modules 110 through a designated angular distance (relative to the base 115) will take a specified amount of time if the PV system 100 is subjected to a specified amount of wind loading that is enough environmental loading to cause the damper 140 to transition to the higher damping

ratio. For example, the higher damping ratio can be selected under wind tunnel testing such that the actuator moves the PV modules 110 thirty degrees relative to the base in 60 seconds while the PV system 100 is subjected to a specified amount of wind loading above a threshold wind speed. The higher damping ratio can be selected to allow faster or slower movements of the PV modules 110, such as 10 seconds, 30 seconds, or 120 seconds.

Other Considerations

**[0023]** The foregoing description of various embodiments of the claimed subject matter has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the claimed subject matter to the precise forms disclosed. Many modifications and variations can be apparent to one skilled in the art. Embodiments were chosen and described in order to best describe the principles of the invention and its practical applications, thereby enabling others skilled in the relevant art to understand the claimed subject matter, the various embodiments, and the various modifications that are suited to the particular uses contemplated.

**[0024]** While embodiments have been described in the context of fully functioning computers and computer systems, those skilled in the art can appreciate that the various embodiments are capable of being distributed as a program product in a variety of forms, and that the disclosure applies equally regardless of the particular type of machine or computer-readable media used to actually effect the distribution.

**[0025]** Although the above Detailed Description describes certain embodiments and the best mode contemplated, no matter how detailed the above appears in text, the embodiments can be practiced in many ways. Details of the systems and methods can vary considerably in their implementation details, while still being encompassed by the specification. As noted above, particular terminology used when describing certain features or aspects of various embodiments should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments

disclosed in the specification, unless those terms are explicitly defined herein. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the embodiments under the claims.

**[0026]** The language used in the specification has been principally selected for readability and instructional purposes, and it cannot have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the invention be limited not by this Detailed Description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of various embodiments is intended to be illustrative, but not limiting, of the scope of the embodiments, which is set forth in the following claims.

## CLAIMS

What is claimed is:

1. A photovoltaic system, comprising:

a collection of photovoltaic modules;

a base supporting the collection of photovoltaic modules; and

a damper coupled between the collection of photovoltaic modules and the base and resisting movement of the photovoltaic modules relative to the base, the damper having a first damping ratio when the collection of photovoltaic modules moves at a first rate relative to the base and a second damping ratio when the collection of photovoltaic modules moves at a second rate relative to the base, wherein the damper passively transitions from the first damping ratio to the second damping ratio.

2. The photovoltaic system of claim 1, further comprising an actuator coupled to the collection of photovoltaic modules and configured to move the collection of photovoltaic modules to change an angle of the collection of photovoltaic modules relative to the base.

3. The photovoltaic system of claim 2, wherein the actuator moves the collection of photovoltaic modules at the first rate.

4. The photovoltaic system of claim 3, wherein environmental loading moves the collection of photovoltaic modules at the second rate, and wherein the second damping ratio is higher than the first damping ratio.

5. The photovoltaic system of claim 2, further comprising a controller in electronic communication with the actuator and configured to drive the actuator to move the collection of photovoltaic modules relative to the base, wherein the damper transitions from the first damping ratio to the second damping ratio independently of the controller.

6. The photovoltaic system of claim 1, wherein the damper supports at least a portion of a load placed on the photovoltaic system by an environmental condition.

7. The photovoltaic system of claim 1, wherein the second damping ratio is greater than critical damping of the photovoltaic system.

8. The photovoltaic system of claim 7, wherein the second damping ratio causes the damper to be fully locked against the movement of the photovoltaic modules relative to the base.

9. The photovoltaic system of claim 7, wherein the second damping ratio causes the damper to permit movement of the photovoltaic modules relative to the base while resisting the movement.

10. The photovoltaic system of claim 1, wherein the damper comprises:

a damper chamber containing a fluid;

a damper piston configured to move through the fluid relative to the damper chamber;

a first port in the damper piston, the first port having a first diameter;

a second port in the damper piston, the second port having a second diameter larger than the first diameter;

a valve configured to open or close the second port such that the second port is open when the collection of photovoltaic modules moves at the first rate relative to the base and the second port is closed when the collection of photovoltaic modules moves at the second rate relative to the base, wherein the fluid contained in the damper chamber flows between the damper chamber and damper piston through both the first and second ports when the second port is open and only through the first port when the second port is closed.

11. The photovoltaic system of claim 1, wherein the second damping ratio allows the collection of photovoltaic modules to move a designated angular distance relative to the base in a specified amount of time under specified wind loading.

12. A photovoltaic system, comprising:

one or more photovoltaic modules;

a base coupled to the one or more photovoltaic modules and supporting the photovoltaic modules;

an actuator coupled to the one or more photovoltaic modules and configured to move the photovoltaic modules to dynamically change an angle of the one or more photovoltaic modules with respect to the base; and

a damper coupled between the photovoltaic modules and the base and resisting movement of the photovoltaic modules relative to the base, the damper having a first damping ratio when the actuator moves the photovoltaic modules and passively transitioning to a second damping ratio that is greater than the first damping ratio when environmental loads are applied to the photovoltaic modules.

13. The photovoltaic system of claim 12, further comprising a controller in electronic communication with the actuator and configured to drive the actuator to move the collection of photovoltaic modules relative to the base, wherein the damper transitions from the first damping ratio to the second damping ratio independently of the controller.

14. The photovoltaic system of claim 12, wherein the damper supports at least a portion of a load placed on the photovoltaic system by an environmental condition.

15. The photovoltaic system of claim 12, wherein the second damping ratio is greater than critical damping of the photovoltaic system.

16. The photovoltaic system of claim 15, wherein the second damping ratio causes the damper to be fully locked against the movement of the photovoltaic modules relative to the base.

17. The photovoltaic system of claim 15, wherein the second damping ratio causes the damper to permit movement of the photovoltaic modules relative to the base while resisting the movement.

18. The photovoltaic system of claim 12, wherein the damper comprises:

a damper chamber containing a fluid;

a damper piston configured to move through the fluid relative to the damper chamber;

a first port in the damper piston, the first port having a first diameter;

a second port in the damper piston, the second port having a second diameter larger than the first diameter;

a valve configured to open or close the second port such that the second port is open when the collection of photovoltaic modules moves at the first rate relative to the base and the second port is closed when the collection of photovoltaic modules moves at the second rate relative to the base, wherein the fluid contained in the damper chamber flows between the damper chamber and damper piston through the second port when the second port is open and through the first port when the second port is closed.

19. The photovoltaic system of claim 12, wherein the second damping ratio allows the collection of photovoltaic modules to move a designated angular distance relative to the base in a specified amount of time under specified wind loading.

20. The photovoltaic system of claim 12, wherein at least one of the photovoltaic modules, the base, or the actuator is designed to withstand an average value of moments applied to the photovoltaic system across a specified period of time.

## ABSTRACT OF THE DISCLOSURE

A photovoltaic system includes a collection of photovoltaic modules, a base supporting the collection of photovoltaic modules, and a damper coupled between the collection of photovoltaic modules and the base. The damper resists movement of the photovoltaic modules relative to the base. The damper has a first damping ratio when the collection of photovoltaic modules moves at a first rate relative to the base and a second damping ratio when the collection of photovoltaic modules moves at a second rate relative to the base, and the damper passively transitions from the first damping ratio to the second damping ratio.

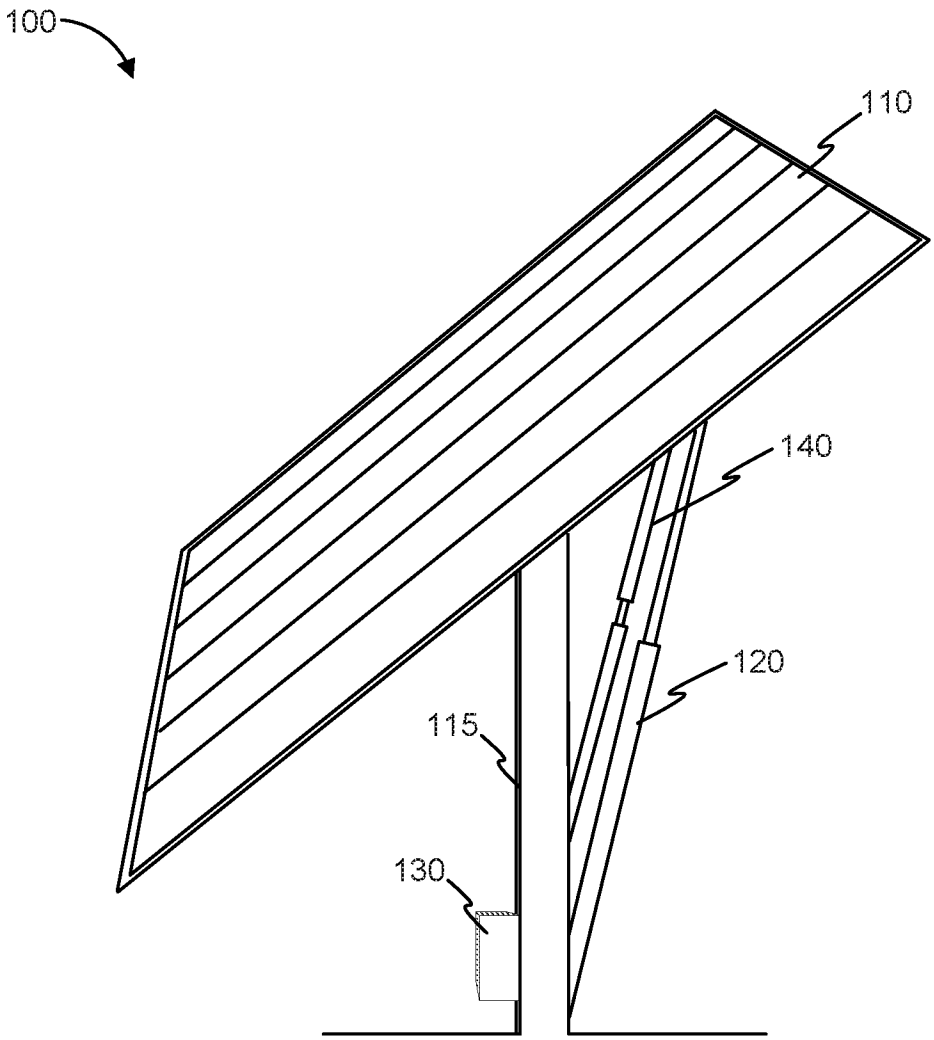


FIG. 1

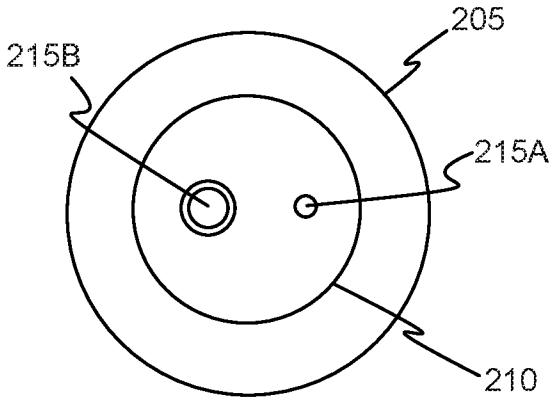


FIG. 2A

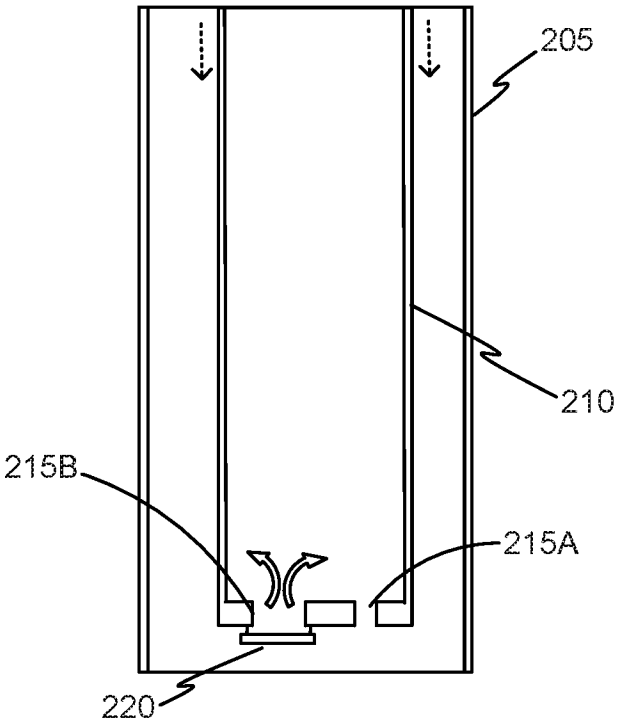


FIG. 2B

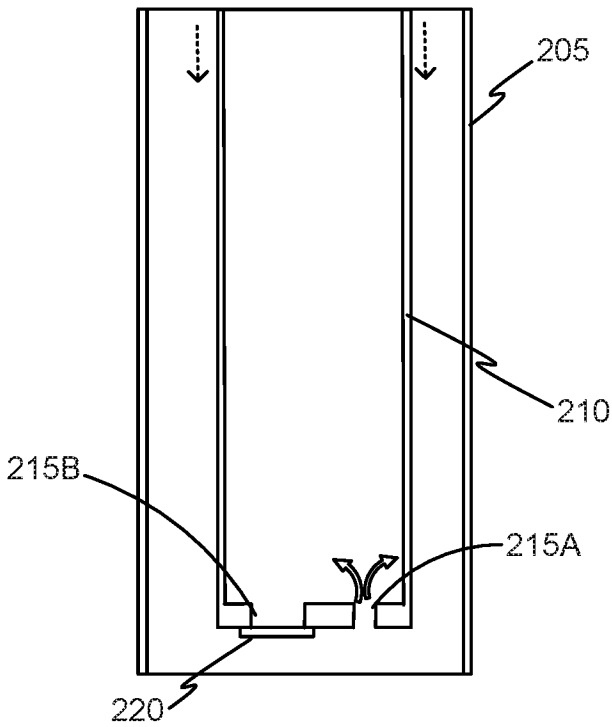


FIG. 2C

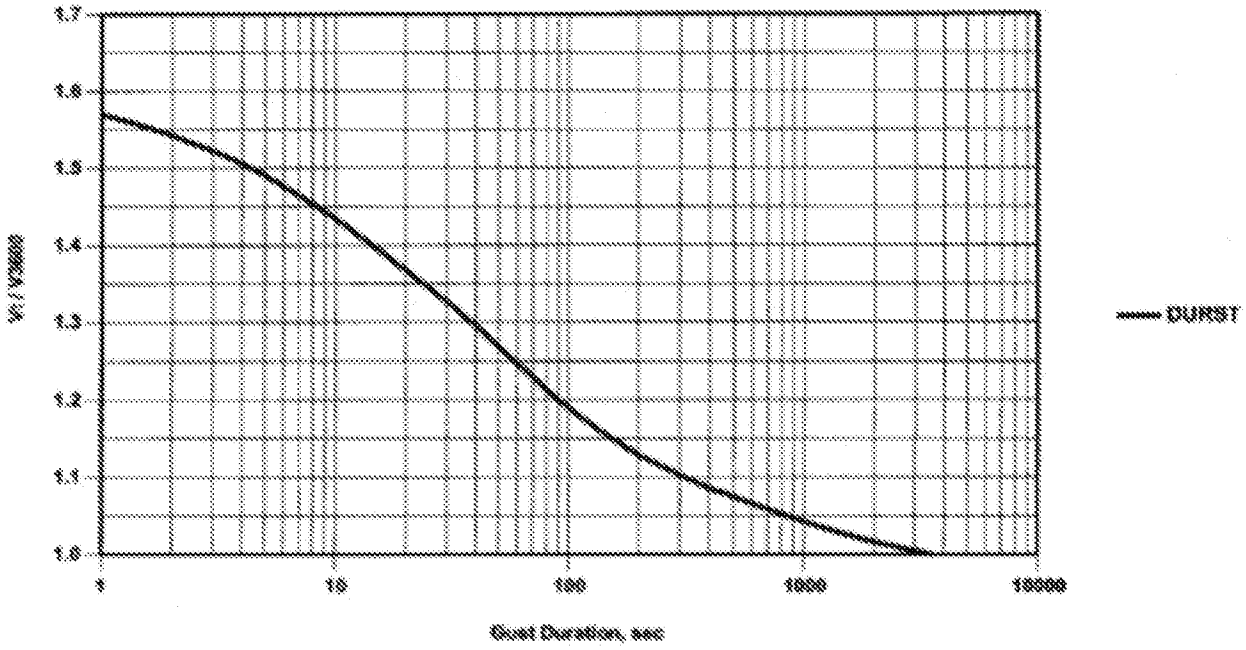


FIG. 3